Piquett Fuels Soil Productivity Risk Map/Soil Risk Evaluation Framework
Metadata and supplemental background information

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Background:

Condition-based NEPA presents a new set of challenges for resource-specific effects analysis. Soils analyses generally pivot on R1 soil quality guidelines, which basically stipulate that no project unit can exceed 15% detrimental soil disturbance (DSD) following project implementation. Historically, this guideline has been applied at the unit scale (i.e. timber stand/harvest unit). With this shift towards analyzing all acreage within a project boundary, accurately and efficiently characterizing existing condition across a large area with limited field reconnaissance in advance of analysis is difficult. Further, anticipating consequences of a suite of project activities without predetermining locations also presents a unique challenge.

To meet this need, a soil risk evaluation framework and accompanying soil risk productivity map were developed for the Piquett Fuels project area. These products loosely draw upon successful past condition-based project analyses conducted on forests in Region 6.

Supporting field reconnaissance:

Soil disturbance monitoring:
In order to assess existing conditions, past harvest units were selected for monitoring using the FACTS activity database. Units were selected to represent a range of years since last entry and a variety of harvest intensities. Some of these activities were implemented prior to modern NEPA analysis in absence of policy surrounding maintenance of long-term soil productivity and without the range of typical design features used to mitigate adverse soil effects. As such, conditions observed within the Piquett Fuels project boundary may not be wholly representative of conditions that may be observed following implementation of project activities. These monitored units, however, likely represent a complete range of disturbed conditions within the project boundary from no human-caused DSD to a "worst-case" situation where units may still be recovering from past management activities.

Units were monitored for detrimental soil disturbance using the Forest Soil Disturbance Monitoring Protocol (FSDMP) (Page-Dumroese et al. 2009) during field season 2019. The FSDMP method is designed to provide a statistically valid rapid assessment of soil conditions based on visual indicators to describe surface conditions that affect site sustainability, hydrologic function, and site productivity. The FSDMP is intended to be used nationwide so that monitoring data will be consistent across the country and at the same time, provide room for local interpretation of whether different levels of impact are detrimental within a given ecological condition. The protocol consists of a randomized transect grid sample within a project unit. A minimum of 30 sample points is required to achieve statistically valid estimates; greater stand variability will require more sample points to provide the same level of statistical confidence. At predetermined frequencies, a suite of visual indicators are assessed and one of four soil disturbance classes are assigned. Class 0 soil disturbance is in effect a natural undisturbed soil condition, while Class 3 disturbance is significantly disturbed through rutting, compaction, burning, topsoil displacement, or some combination of these attributes. See Page-Dumroese et al. 2009 for more detailed discussion of the FSDMP protocol and how soil disturbance classes are defined.

Based on broader regional convention and guidance from FSDMP protocol authors, Class 2 and 3 soil disturbances are generally considered detrimental.

Assumptions/inherent limitations of the FSDMP monitoring protocol:
As a result of the FSDMP using predetermined sampling frequencies within a grid pattern, sample points that provide critical site context may be missed at locations between grid sampling points. Accordingly, more detailed site characterizations are generally required to complement data collected using the FSDMP method. These more detailed site characterizations generally consist of one or multiple abbreviated soil pedon descriptions further informed by ancillary site characteristics collected while randomly transecting through units of interest. The Piquett Fuels CE takes a condition-based analysis approach and assumes that more intensive field reconnaissance would occur under the project implementation plan; after project units are established and specific management activities proposed, more intensive field work would take place as needed.

Because of time constraints, no more than 30 sample points were collected within any given unit. So, while statistically valid DSD estimates may not have been achieved in all units, monitoring data nonetheless provides reasonable estimates of unit-wide DSD. Of the seven units monitored, only two were found to have any persisting detrimental soil disturbance. Observed DSD in these two units was 7% and 10%. The remainder of units were found to have no persisting DSD, but legacy disturbance attributes were observed in two other past harvest units, such as lack of surface organic matter and obvious differences in extent and diversity of understory vegetation resulting from past disturbance.

Past application of the FSDMP has found substantial error in estimated DSD, particularly in large (in general, on the order of 50 acres or more) units where very few DSD observations have been made (e.g. Efta 2017). A change in transect trajectory of even one foot in one direction or another could skew DSD estimates drastically in units where only two or three instances of detrimental disturbance may be observed. It is acknowledged that sampling error will be influenced by not taking more than 30 observation points within any stand regardless of preexisting DSD extent. Regardless, point- or planar-intersect methods may only be totally accurate when a cost-prohibitively high number of sample points are accumulated (e.g. in a fuels sampling method context, Sikkink and Keane 2008 as described in Holley and Keane 2010). The discussion above is not to diminish the value or utility of the FSDMP, but rather to contextualize what it provides the user.

The FSDMP has been used in numerous instances for tracking recovery over time (e.g. Coleman 2012, Gries and Efta 2012). In some cases, soil recovery curves have been developed to help draw inference as to the likely duration of compromise in soil productivity following project implementation. Soil disturbance indicators evaluated through the FSDMP, however, in some cases may not be ideal for tracking DSD recovery through time. This is evidenced by observations of no persisting DSD in two units but obvious signs of past disturbance persisting between 30 and 50 years.

<u>Analysis:</u>

FSDMP data were collected using the R1 Soil Disturbance Monitoring Form developed in Survey123 and accessible via ArcGIS Online. Data were accessed via AGOL account and downloaded from ArcMap as an attribute table. The spreadsheet containing the collected field data is titled "Piquett_soilsDSD_1.xlsx" and is stored on the T drive at T:\FS\NFS\Bitterroot\Project\SouthZone\PiquettCreek\GIS\Workspace\Soils\jefta.

In light of the above discussion, for the purposes of this analysis those units where persisting management-induced soil disturbance was found were lumped into "disturbed sites" and used as a population for the rest of the analysis.

In order to better discern what edaphic, physiographic, climatic, and/or management-specific controls may be influencing persistence of detrimental soil disturbance, further analysis was undertaken. Survey 123 DSD data is represented as a single point, so monitored units were manually selected from the FACTS data layer and used to develop a new layer (i.e. create layer from selected features). "Disturbed" units were overlaid with bedrock geology and soils map units and visually evaluated in ArcGIS to discern the degree of alignment. Harvest activity, harvest method, and years since past harvest were reviewed concurrently.

In addition to the above analysis, summary statistics for gridded climatic water deficit data were determined for the disturbed units. This was done using the Zonal Statistics as Table tool in ArcGIS. Zonal statistics were run against annual climatic water deficit data (zonal statistics as table, "Zonalst_Piquett5") using the disturbed units as zonal boundaries. Zonal stats were joined to the monitored units layer in ArcGIS. The 30 meter water deficit data available at T:\FS\NFS\R01\Program\2500WatershedAirMgmt\GIS\WorkSpace\varcher\runoff\deficit\DEF_30m_wgs_tps_predict_v2.tif was used for this analysis. Further discussion on this dataset can be found below.

<u>Results:</u>

As noted above, seven units were evaluated within the project area. Four of those seven displayed some degree of persisting soil disturbance and two of those units were observed to have detrimentally disturbed soils.

Bedrock geology and soils map units did not appear to play any overriding role in determining persistence of soil disturbance associated with past project activities. Bedrock geology is relatively homogenous across the project area, and soil characteristics as mapped had no distinct correlation with disturbed units. Though the sample population was quite small, neither harvest type (and, by extension, harvest method) nor time since harvest appeared to have any bearing on whether soil disturbance was still on site.

Evaluation of monitored units against climatic water deficit yielded a distinct pattern. Persisting soil disturbance, be it DSD or otherwise, within monitored units clearly corresponded with a climatic water deficit break of 500 mm (Figure 1, Table 1).

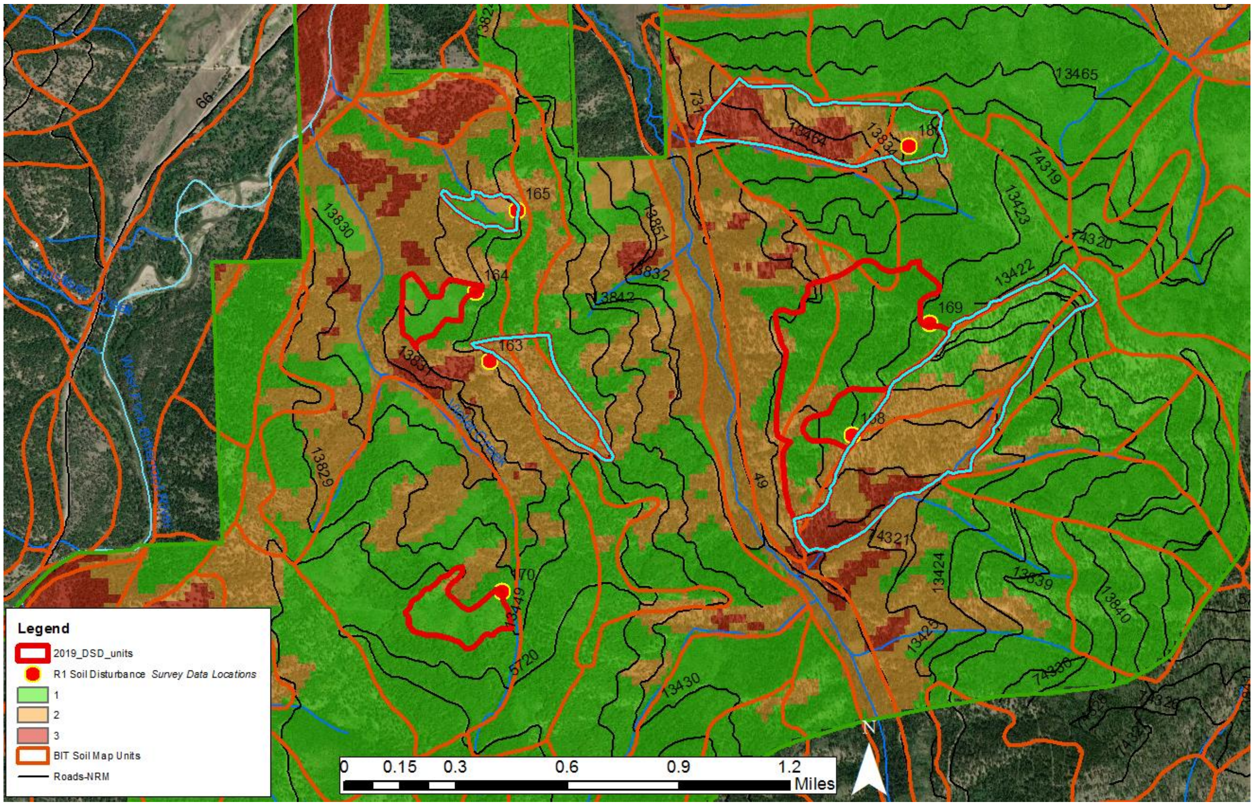


Figure 1. Portion of the Piquett Fuels project area with inventoried past harvest areas overlaying climatic water deficit. The four highlighted units denote areas where persisting signs of soil disturbance (both detrimental and non-detrimental) were observed in 2019.

Table 1. Mean water deficit value associated with past harvest units monitored for past soil disturbance during the 2019 field season. Bold lines/gray highlighted lines denote units where persisting soil disturbance was observed.

Unit ID	Year last harvested	Mean annual water deficit (mm)
180	**1965**	**535**
168	**1966**	**515**
169	1973	486
170	1973	480
165	**1988**	**507**
163	**1989**	**521**
164	1989	496

Field observation within the Mud Creek project area found strong alignment between climatic water deficit data and changes in understory and overstory vegetation species assemblages, abundance, and productivity. Climatic water deficit (PET-AET) data incorporates a number of independent variables that have been looked at independently in the past as being important drivers of vegetative productivity. For example, the Penman-Monteith model for calculating PET accounts for temperature, latitude, elevation, wind speed, solar radiation, albedo and vapor pressure deficit and AET is computing using a

Thornthwaite-Mather climatic water balance model that accounts for soil water content (Dobrowski et al. 2013; Abatzoglou et al. 2014; Z. Holden, personal communication).

Summary/conclusion:
Limited available field data and cursory analysis suggest that annual climatic water deficit may provide a better metric for determining soil susceptibility to persistence of soil disturbance and associated potential for compromise in long-term soil productivity. While more field data is necessary to validate this hypothesis, available data and field observation from adjacent project areas suggests that application of climatic water deficit as a surrogate for post-disturbance soil resilience is a reasonable approach to take for development of a soil risk evaluation framework under condition-based soils analysis for the Piquett Fuels project.

Primary working map:
T:\FS\NFS\Bitterroot\Project\SouthZone\PiquettCreek\GIS\Workspace\Soils\

- Piquett_soilrisk_07222019.mxd

<u>Application:</u>
Applying the above analysis for soil resource management within the Piquett Fuels project area, a soil productivity risk matrix was developed. Based on the water deficit threshold for persistent soil disturbance established through analysis and further interpretation of overstory tree density within aerial photo interpretation, continuous water deficit data were reclassified into three categories: low (371-500 mm), high (500-550 mm), and very high (550-589 mm). The inverse of these categories, in turn, reflects the perceived post-disturbance soil resilience potential within the project area.

Areas where past management activities have been undertaken may have still have past soil disturbance manifesting itself on-site, so this factor was included in the risk matrix. Rounding out the soil productivity risk matrix was those areas where known soil disturbance persists within past activity areas. Each soil risk category was assigned a number.

Below is the preliminary draft soil risk matrix:

Soil resilience (inverse of climatic water deficit)	**Water deficit range**	**No known past activities**	**Past activities**	**Past activities with known DSD**
High	371-500	1	5	10
Low	500-550	2	6	11
Very Low	550-589	3	7	12

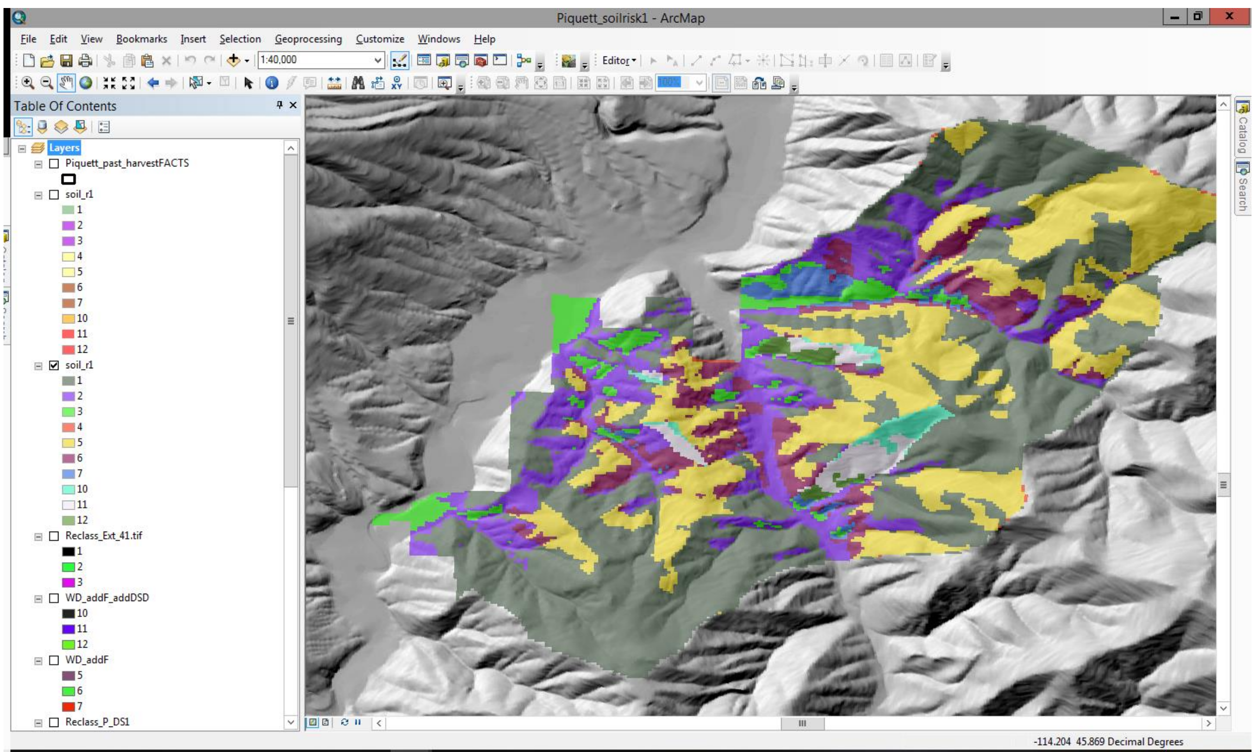
A map was developed in tandem to provide spatial representation of the risk matrix. The primary working map for this work is T:\FS\NFS\Bitterroot\Project\SouthZone\PiquettCreek\GIS\Workspace\Soils\Piquett_soilrisk1.mxd. Tools/steps used/layer names for development:

- "Clip" water deficit raster to Piquett Fuels extent: completed in Piquett_soilrisk_07222019.mxd-

- Extract by mask, layer name Ext_P30m

- Convert Ext_P30m from continuous to categorical data: also completed in Piquett_soilrisk_07222019.mxd
    - Reclassify, layer name Reclass_Ext_4
- Convert FACTS data to raster: P_FACTS_R2
    - Reclassify to 4: Reclass_P_FA1
- Convert FACTS polygons where DSD was observed: P_DSD_R2
    - Reclassify to 5: Reclass_P_DS1
- Create draft soil risk raster: soil_r1
    - Raster Calculator: Reclass_Ext_4 + Reclass_P_FA1 + Reclass_P_DS1
    - Other layers in map were a failed attempt using the "Add" raster tool

A screen shot of this preliminary map is below:

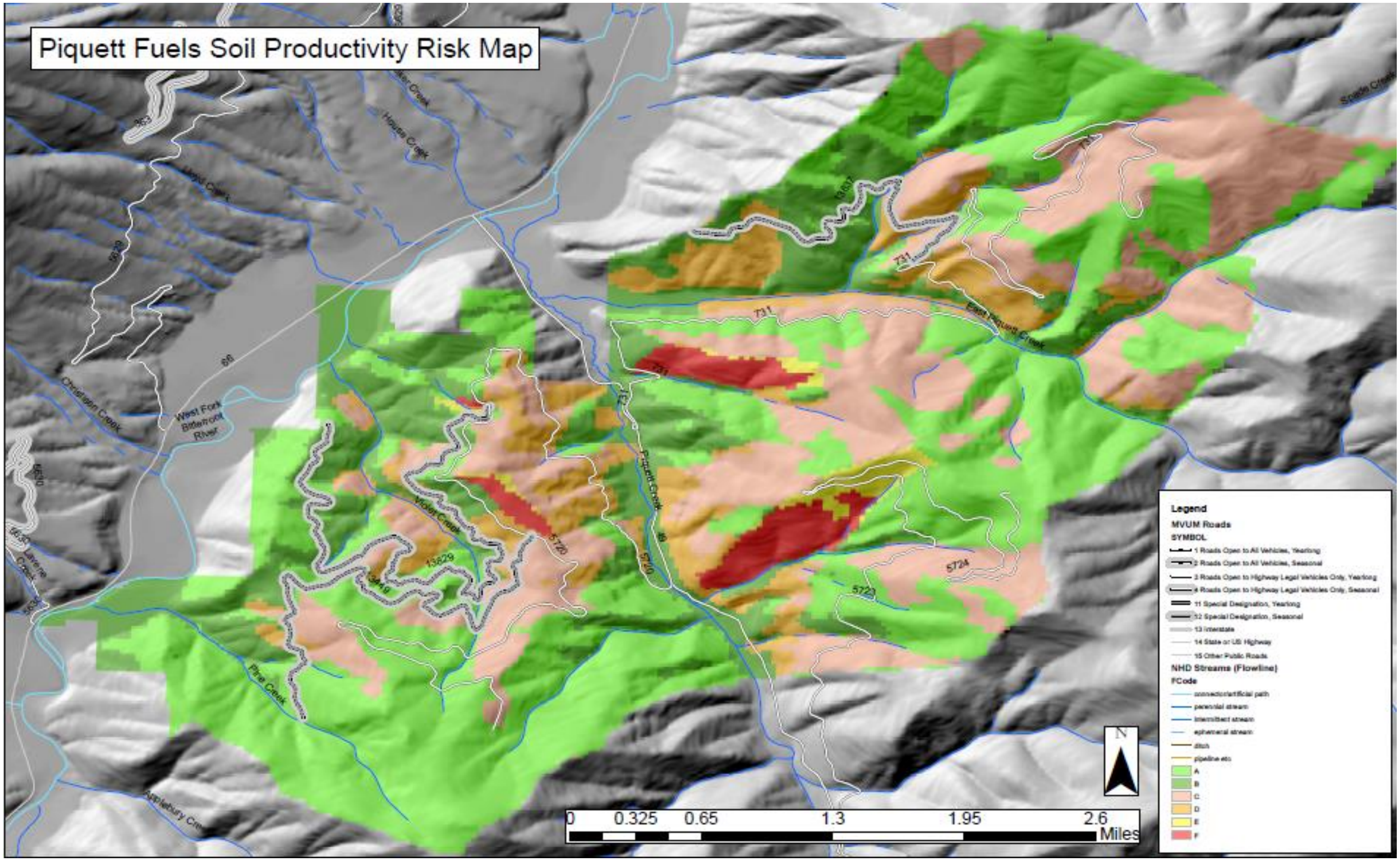


Upon review, the preliminary risk matrix and associated risk map were deemed too complex. In effort to simplify, "low" and "very low" soil resilience (i.e. climatic water deficit) categories were lumped together, producing the following risk matrix, soil risk category descriptions, and map.

Soil resilience (inverse of climatic water deficit)	Water deficit range	No known past activities	Past activities	Past activities with known DSD
High	371-500	A	C	E
Low	500-589	B	D	F

Soil Risk Category (SRC)	Narrative Description
A	There are no documented past management activities within these areas and relative soil resilience within this area is considered high (i.e. better than the rest of the project area). **Actions:** Proposed project activities are subject to the standard range of design features contained in Appendix B.
B	No known past activities have occurred within these areas, but soil resilience following disturbance will be more limited than in SRC A. Management activities have potential to have more prolonged impacts than in SRC A. **Actions:** Careful selection of management activities may be required to ensure long-term soil productivity and additional design features beyond those contained in Appendix B may be warranted.
C	Past management activities have been documented in these areas, but there are currently no documented instances of persisting short- or long-term soil productivity compromise from past project implementation. Relative soil resilience is considered high. **Actions:** Inventory of persisting detrimental soil disturbance will be required within these project areas. Proposed project activities are subject to the standard range of design features contained in Appendix B. Should persisting DSD from past management activities be found during field reconnaissance, proposed project activities may need to be modified to avoid adverse soil resource effects.
D	Past management activities have been documented in these areas, but there are currently no documented instances of persisting short- or long-term soil productivity compromise from past project implementation, but likelihood of persistence is higher than under SRC C. Relative soil resilience is limited. **Actions:** Careful selection of management activities may be required to ensure long-term soil productivity and additional design features may be warranted. Should persisting DSD from past management activities be found during field reconnaissance, proposed project activities may need to be modified to avoid adverse soil resource effects.
E	Past management activities in these areas has created persisting long-term detrimental soil disturbance. More information is needed to discern the extent to which natural site potential versus differences in past harvest practices may have influenced persisting concerns in these areas. **Actions:** Careful selection of management activities may be required to ensure long-term soil productivity and additional design features may be warranted. Proposed project activities may need to be modified to avoid adverse soil resource effects.

F	Past management activities in these areas has created persisting long-term detrimental soil disturbance. Management activities may have more prolonged impacts than in SRCs A, C, and E. **Actions:** Careful selection of management activities is required to ensure long-term soil productivity and additional design features may be warranted. Avoidance of commercial harvest or prescribed burning in these areas should be considered as well as exploration of potential restoration opportunities. If project activities are deemed necessary and/or appropriate, additional design features may be necessary.


Piquett Fuels Soil Productivity Risk Map
West Fork Bitterroot River
Piquett Creek
East Piquett Creek
Violet Creek
Pine Creek
Applebury Creek
Christisen Creek
Houle Creek
731
5720
5724
5723
13829
N
0
0.325
0.65
1.3
1.95
2.6
Miles
Legend
MVUM Roads
SYMBOL
1 Roads Open to All Vehicles, Yearlong
2 Roads Open to All Vehicles, Seasonal
3 Roads Open to Highway Legal Vehicles Only, Yearlong
4 Roads Open to Highway Legal Vehicles Only, Seasonal
11 Special Designation, Yearlong
12 Special Designation, Seasonal
13 Interstate
14 State or US Highway
15 Other Public Roads
NHD Streams (Flowline)
FCode
connector/artificial path
perennial stream
intermittent stream
ephemeral stream
ditch
pipeline etc
A
B
C
D
E
F

Final working map (final layers, also mxd used for generating PDF map products):
T:\FS\NFS\Bitterroot\Project\SouthZone\PiquettCreek\GIS\Workspace\Soils\Piquett_soilrisk1_map.mxd

Final reclassify from soil_r1 to final map: layer name is Reclass_soil1, changed alias in table of contents from number 1-6 to letters A-F.

Final layers:
T:\FS\NFS\Bitterroot\Project\SouthZone\PiquettCreek\GIS\Workspace\Soils\jefta\Piquett_data.gdb
SPR_map1 (grid), SPR_map1_polygon (polygon)

<u>References:</u>

Abatzoglou, J.T., R. Barbero, J. Wolf, and Z. Holden (2014). Tracking Interannual Streamflow Variability with Drought Indices in the U.S. Pacific Northwest. J. Hydrometeorology 15: 1900-1911.

Coleman, A. 2012. FY2011 Annual Soil Monitoring Report- Timber Sale Monitoring. Helena National Forest.

Dobrowski, S., J. Abatzoglou, A. Swanson, J. Greenberg, A. Mysneberge, Z.A. Holden and M. Schwartz (2012). The climate velocity of the contiguous United States during the 20th century. Global Change Biology.19:241-251.

Gries, J., and Efta, J.A. 2012. 2011 Timber Harvesting Soil Disturbance Monitoring Report for the Hiawatha National Forest. 15 p.

Holley, V.J., and Keane, R.E. 2010. A visual training tool for the Photoload sampling technique. Gen. Tech. Rep. RMRS-GTR-242. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 235 p.

Page-Dumroese, Deborah S.; Abbott, Ann M.; Rice, Thomas M. 2009. Forest Soil Disturbance Monitoring Protocol: Volume I: Rapid assessment. Gen. Tech. Rep. WOGTR-82a. Washington, DC: U.S. Department of Agriculture, Forest Service. 31 p: method application.